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Mushrooms as functional foods

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Summary: In this study I compared the nutritional composition of the commonly consumed fruits and vegetables with three of the most important cultivated mushrooms: white button mushroom (*Agaricus bisporus* LANGE/IMBACH), oyster mushroom (*Pleurotus* spp. JACQ. P. KUMM.) and shiitake (*Lentinula edodes* BERKELY/PEGLER). I compared the energy content and some mineral values (sodium, potassium, calcium, magnesium and selenium), as these play a major role in the nutritional value of mushrooms. The focus was on the vitamin B group and the vitamin D content in mushrooms, which is especially important due to the fact that fruits and vegetables do not contain this vitamin.

Nowadays one of the main research and experimental topic is finding possible ways for enhancing the vitamin D content in cultivated mushrooms by UV-light. The Corvinus University of Budapest is running a project in this research area as well.

Based on the data presented in this study we can say that mushrooms and therefore the cultivated mushrooms have an honourable place within the group of functional foods.

Key words: functional foods, cultivated mushrooms (white button mushroom, oyster mushroom, shiitake), minerals, vitamin B group, vitamin D

Introduction

The category functional foods (FOSHU = foods for specified health uses) was first introduced in the middle of the 1980's in Japan and in 1992 functional foods' was set as an act into the regulatory system (In: *Cheung*, 2008).

According to Japan's Nutrition Improvement Act, functional foods have to meet the following demands: consumption of this food must improve the health condition, its different components must have beneficial effect on the health and this should be proved by exact analysis, moreover the ingredients of this food must be of natural origin (*Shimizu*, 2003).

Mushrooms constitute the second largest group in the living world after the group of insects. There are approximately 1,5 millions of fungi all over the world (*Hawksworth*, 2001). Around 120 000 species have been identified until now and of this amount 14 000 are the macrofungus. The macrofungus have a distinctive fruit body, large enough to be seen with eye and to be picked by hand (*Chang-Miles*, 1992). Around 3 000 species are edible and among this group there are 700 species with some known medicinal effects. The characteristics of some species are still partially or completely unknown and among them approximately 1 400 species are more or less poisonous. „Fly agaric" (*Amanita muscaria*) or tale mushroom has psychoactive properties, while the death cap (*Amanita phalloides*) is extremely poisonous.

In the past centuries, people from different parts of the world had a very different view on mushrooms. In the ancient times the mushrooms were called the food of the Gods. The Pharaohs in the ancient Egypt were consuming mushrooms not only because of their special taste but because of the magical (hallucinogen) characteristics too. The ancient Greeks looked at mushrooms as providers of physical and mental power, while the Chinese put forward the mushrooms'health benefits.

Even the experts have underestimated the nutrient value of edible mushrooms. In the past decades, experiments have proved that the nutritional value of mushrooms is higher than of fruits and vegetables (*Lelley-Vetter*, 2004; *Lelley-Vetter,* 2005; *Vetter* et al., 2005).

According to the results of various experiments the value of the edible mushrooms are determined by following generally valid characteristics:

- low energy level;
- very low sodium concentration;
- high content of some minerals (potassium, calcium);
- high content of some trace elements, especially selenium;
- high content of several vitamins, mainly vitamin B group and vitamin D_2.

In the comparison I included three species of the most important mushrooms cultivated in our country and the world: *Agaricus bisporus* = white button mushroom *(Figure 1)*, *Pleurotus* spp. = oyster mushroom *(Figure 2)* and *Lentinula edodes* = shiitake *(Figure 3)*. I have selected some of the most commonly consumed vegetables and fruits in Hungary to compare the content of energy, main minerals, vitamin B group and vitamin D. The main source for the data of the nutritional composition of fruits and vegetables are from *Bíró-Lindner* (1999) and the contents of different mushrooms are from *Vetter (*1990, 1994 and 2000).

Energy content of mushrooms

The energy content of edible mushrooms is generally low, which allows them to be used in low-energy diets (In: *Cheung*, 2008).

The daily requirement of energy for adults comes up to approx. 1 800–3 100 kcal.

A serving of 100 g fresh edible mushrooms provides only 1,4–1,6% of the daily energy requirement for adults *(Table 1)*.

Table 1. Average energy kJ (kcal) content in 100 g vegetables, fruits and mushrooms (fresh)

Average energy kJ (kcal) content in 100 g vegetable and fruit (fresh)			
Vegetables		**Fruits**	
Name		**Name**	
cabbage	134 (32)	apple	130 (31)
carrot	168 (40)	apricot	202 (48)
cauliflower	126 (30)	**banana**	**441(105)**
celeriac	121 (29)	grape	328 (78)
cucumber	50 (12)	grapefruit	151 (36)
green beans	172 (41)	lemon	113 (27)
green peas	**378 (90)**	orange	172 (41)
green pepper	84 (20)	peach	172 (41)
kohlrabi	164 (39)	pear	218 (52)
lettuce	71 (17)	plum	244 (58)
spinach	84 (20)	raspberry	122 (29)
tomato	97 (23)	sour cherry	218 (52)
water melon	122 (29)	strawberry	147 (35)
Average energy kJ (kcal) content in 100 g mushrooms (fresh)			
white button mushroom	168 (40)		
oyster mushroom	164 (39)		
shiitake	148 (35)		

Table 2. Average sodium and potassium content (mg) in 100 g vegetables, fruits and mushrooms (fresh)

Average content (mg) in 100 g vegetables and fruits (fresh)					
Vegetables			**Fruits**		
Name	**Sodium**	**Potassium**	**Name**	**Sodium**	**Potassium**
cabbage	23,0	216,0	apple	2,0	112,0
carrot	70,0	360,0	apricot	6,1	226,
cauliflower	11,0	175,0	**banana**	**22,0**	**500,0**
celeriac	**100,0**	370,0	grape	2,3	195,0
cucumber	7,0	150,0	grapefruit	–	–
green beans	1,0	229,0	lemon	4,3	275,0
green peas	8,0	325,0	orange	2,6	255,0
green pepper	4,0	160,0	peach	1,7	183,0
kohlrabi	26,0	300,0	pear	2,3	100,0
lettuce	16,0	261,0	plum	3,9	240,0
spinach	**24,0**	**526,0**	raspberry	3,9	172,0
tomato	5,0	240,0	sour cherry	4,7	186,0
water melon	4,9	147,0	strawberry	4,6	145,0
Average content (mg) in 100 g mushrooms (fresh)					
white button mushroom	**5,0**	**510,0**			
oyster mushroom	**2,0**	**340,0**			
shiitake	**2,0**	**250,0**			

Minerals in mushrooms

Cultivated mushrooms are good source of minerals. The fruiting bodies of the mushrooms – while heaving a low **sodium** level – contain high amounts of potassium, which is one of the most important mineral in human nutrition. The sodium content of different vegetables and fruits, furthermore mushrooms can be found in Table 2.

Potassium is mainly supplied by vegetables, fruits, meat and fish. Mushrooms usually contain more potassium than most fruits and vegetables. Mushrooms, like white button mushroom usually contain more potassium than most fruits and vegetables (except spinach and banana) *(Table 2)*.

The daily requirement of sodium for adults comes up to approx. 550 mg.

100 g fresh mushrooms cover only 0,4–0,9% of daily sodium demand.

The daily requirement of potassium for adults is about 2000 mg, about 100 g fresh mushrooms cover 12,5–25,5% of the daily potassium demand.

Calcium – as well as being the most abundant mineral in the human body – provides the structure for our teeth and bones.

The daily requirement of calcium for adults comes up to approx. 1 000–1 200 mg.

100 g of mushrooms contain 60–80 mg of calcium, 5,5–7,5% of the daily demand *(Table 3)*.

Magnesium is essential for good health; it helps to maintain normal muscle and nerve function. Magnesium keeps heart rhythm steady, supports a healthy immune system and keeps the bone structure.

The daily requirement of magnesium for adults comes up to approx. 300–400 mg.

100 g of fresh mushrooms contain 15–16 mg of magnesium, 4,3–4,6% of the daily demand *(Table 3.)*

In the past two decades, the importance of selenium in human health was recognized. This mineral works as an antioxidant, protecting body cells from damage that might lead to heart and cancer diseases.

According to *Bíró* (2004) the daily intake of selenium should be 30-70 μg. The main sources of selenium are meat, fish and eggs. Most of fruits and vegetables contain less than 1,0 μg/100 g selenium (*Morris–Levander,*1970). The exceptions are garlic and various mushroom types. Mushrooms are one of the richest, natural sources of selenium. Selenium content in *Agaricus bisporus* varies dramatically (Table 4). This derives from the differences in the ingredients of compost. The white button mushroom extracts selenium from compost very well. Many experiments prove that white mushroom compost derived from wheat straw that grows in selenium-rich soil, produces fruiting bodies with higher amount of selenium, that those compost which contain wheat straw grown in selenium-poor areas. *Agaricus bisporus* can absorb more selenium therefore we can supplement the compost and the casing soil by different selenium

Table 3. Average calcium and magnesium content (μg) in 100 g vegetables, fruits and mushrooms (fresh)

Average content (mg) in 100 g vegetables and fruits (fresh)					
Vegetables			Fruits		
Name	**Calcium**	**Magnesium**	**Name**	**Calcium**	**Magnesium**
cabbage	33,0	20,0	apple	5,5	6,0
carrot	28,0	35,0	apricot	13,8	14,0
cauliflower	26,0	21,0	**banana**	**110,0**	**60,0**
celeriac	34,0	**60,0**	grape	28,2	14,0
cucumber	18,0	16,0	grapefruit	-	-
green beans	32,0	16,0	lemon	14,0	20,0
green peas	41,0	42,0	orange	43,8	22,0
green pepper	14,0	12,0	peach	5,7	10,0
kohlrabi	43,0	24,0	pear	15,7	10,0
lettuce	28,0	19,0	plum	16,0	16,0
spinach	**133,0**	53,0	raspberry	27,3	24,0
tomato	9,0	7,0	sour cherry	31,3	15,0
water melon	19,4	15,0	strawberry	28,1	18,0
Average content (mg) in 100 g mushrooms (fresh)					
white button mushroom	**80,0**	**15,0**			
oyster mushroom	**70,0**	**16,0**			
shiitake	**60**	**16,0**			

compounds (*Vetter–Lelley,* 2004; *Fehérváry-Póczik* et al., 2005). White button mushroom supplemented with selenium fully corresponds to functional food requirements.

The daily requirement of selenium for adults is around 30 to 70 μg. 100 g fresh mushrooms contain 4–32 μg of selenium, 8–64% of the daily requirement.

Table 4. Average selenium content (μg) in 100 g vegetables, fruits and mushrooms (fresh)

Average selenium content (μg) in 100 g vegetable and fruit (fresh)			
Vegetables		Fruits	
Name	**Selenium**	**Name**	**Selenium**
cabbage	2,2	apple	0,3
carrot	2,2	apricot	0,3
cauliflower	0,6	banana	1,0
garlic	**27,6**	grape	0,3
green beans	0,6	lemon	0,0
green pepper	0,6	orange	1,4
spinach	1,0	peach	0,4
tomato	0,5	pear	0,6
Average content (μg) in 100 g mushrooms (fresh)			
white button mushroom	**14,0–32,0**		
oyster mushroom	**15,0**		
shiitake	**4,0**		

Group of vitamin B

Vitamin B is the global name given to a number of related chemicals. All the B vitamins are water soluble. They work together to help break down carbohydrates into glucose, metabolise facts and protein and ensure the correct functioning of the central nervous system (www. shoppingtrolley. net/vitamin-guide. shtml. 2010.04.17).

Cultivated mushrooms are a rather good source of several vitamins, such as thiamin (B_1), riboflavin (vitamin B_2), niacin or nicotinic acid (vitamin B_3), pantothenic acid (vitamin B_5) and folic acid (vitamin B_9).

Vitamin B_1 (thiamin) is mainly supplied by wholemeal bread, liver, bean, pea and yeast.

A deficiency of B_1 can lead to beriberi, a disease of the nervous system. Thiamin content in mushrooms is quite low, ranging from 40 to 60 μg/100 grams in fresh fruit body. Most vegetable's and fruit's thiamine content is similar to mushrooms except green peas, green beans, tomato and banana *(Table 5)*.

The daily requirement of thiamin for adults is 1 000–1 300 μg.

About 100 g fresh mushrooms cover 3,5–5,2% of the daily thiamine demand.

Vitamin B_2 (riboflavin) helps to maintain healthy red blood cells and promotes good vision and healthy skin. Liver, yeast, milk, meat and fish are rich in vitamin B_2.

The vitamin B_2 content in mushrooms is higher than that generally found in vegetables or fruits (except spinach and green beans) as shown in Table 5.

The daily requirement of vitamin B_2 for adults comes up to approx. 1200–1500 μg.

About 100 g fresh mushrooms cover 8,0–20,0% of the daily riboflavin demand.

Table 5 Average thiamine and riboflavin content (μg) in 100 g vegetables, fruits and mushrooms (fresh)

Average content (μg) in 100 g vegetables and fruits (fresh)					
Vegetables			Fruits		
Name	**Thiamine (B_1)**	**Riboflavin (B_2)**	**Name**	**Thiamine (B_1)**	**Riboflavin (B_2)**
cabbage	40	60	apple	50	50
carrot	50	50	apricot	20	30
cauliflower	60	100	banana	160	*80*
celeriac	40	75	grape	50	50
cucumber	60	50	grapefruit	40	20
green beans	200	**200**	lemon	60	20
green peas	200	150	orange	70	40
green pepper	50	30	peach	20	20
kohlrabi	50	50	pear	30	30
lettuce	60	100	plum	50	20
spinach	80	**200**	raspberry	20	30
tomato	100	60	sour cherry	50	20
water melon	40	20	strawberry	30	70
Average content (μg) in 100 g mushrooms (fresh)					
white button mushroom	60	130			
oyster mushroom	40	110			
shiitake	60	**270**			

Vitamin B_3 (niacin) helps to control the release of energy from protein, fat and carbohydrate, which promotes the functioning of the digestive and nervous system. The main direct sources of B_3 vitamin in the diet include meat and cereals. Deficiency in B_3 can lead to a disease called pellagra, whose main symptoms include dementia, skin and sleep problems. It is virtually unheard in the Western World, although still occurs in some parts of China, Africa and India.

Cultivated mushrooms are very rich in niacin: the content varies from 1 100–5 200 µg/100 g fresh mushrooms *(Table 6).*

The daily requirement of vitamin B_3 for adults is around 13 000–17 000 µg.

About 100 g fresh mushrooms cover 7,5–35% of the daily niacin demand *(Figure 6).*

Vitamin B_5 (pantothenic acid) occurs naturally in mushrooms. It plays a numerous essential metabolic roles in the human body, including providing assistance with the production of hormones.

The daily requirement of panthotenic acid for adults is 6 000 µg.

100 g serving of mushrooms cover 8,5–30% of the recommended daily dietary intake of pantothenic acid *(Table 6).*

Table 6. Average niacin and pantothenic acid content (µg) in 100 g vegetables, fruits and mushrooms (fresh)

Average content (µg) in 100 g vegetables and fruits (fresh)					
Vegetables			Fruits		
Name	**Niacin (B_3)**	**Pantothenic acid (B_5)**	**Name**	**Niacin (B_3)**	**Pantothenic acid (B_5)**
cabbage	1000	100	apple	500	90
carrot	1500	300	apricot	700	120
cauliflower	500	440	banana	500	150
celeriac	400	400	grape	400	60
cucumber	100	120	grapefruit	200	170
green beans	1000	470	lemon	100	200
green peas	1000	50	orange	200	170
green pepper	200	190	peach	900	100
kohlrabi	300	200	pear	300	50
lettuce	500	110	plum	500	90
spinach	1000	110	raspberry	400	160
tomato	500	20	sour cherry	300	80
water melon	200	700	strawberry	300	40
Average content (mg) in 100 g mushrooms (fresh)					
white button mushroom	**4600**	1800			
oyster mushroom	**5200**	500			
shiitake	**1100**				

Vitamin B_9 (folic acid) is found in a number of vegetables (e.g. cabbage, carrot, kohlrabi, spinach). Folic acid is responsible for the formation of red and white blood cells in bone marrow. For instance pregnant women are encouraged to increase their folic acid intake to ensure proper foetal development.

Mushrooms contain moderately high amounts of Vitamin B_9 (except oyster mushroom that is rather rich this vitamin, *Table 7*).

Table 7. Average folic acid content (µg) in 100 g vegetables, fruits and mushrooms (fresh)

Average content (µg) in 100 g vegetables and fruits (fresh)			
Folic acid			
Vegetables		Fruits	
Name		**Name**	
cabbage	–	apple	6,0
carrot	6,4	apricot	3,0
cauliflower	34,0	banana	13,0
celeriac	4,4	grape	5,2
cucumber	14,0	grapefruit	7,0
green beans	41,0	lemon	4,0
green peas	13,0	orange	17,0
green pepper	13,0	peach	2,5
kohlrabi	–	pear	–
lettuce	25,0	plum	1,9
spinach	**66,0**	raspberry	–
tomato	37,0	sour cherry	–
water melon	2,2	strawberry	–
Average content (µg) in 100 g mushrooms (fresh)			
white button mushroom	45,0		
oyster mushroom	64,0		
shiitake	30,0		

The daily requirement of vitamin B_9 for adults is 400 µg.

100 g serving of mushrooms provides 7,5–16,0% of the recommended daily dietary intake of folic acid.

Vitamin D is a fat soluble vitamin. There are only a few natural sources of vitamin D_2. It is found mostly in seafood and animal products (fish and fish liver, milk, butter and cheese), but no plant-products (fruit or vegetables) consist any of it. Therefore vegetarians, who are not consuming even milk products, are at risk of vitamin D deficiency (*Jasinghe* et al., 2005; *Mattila* et al., 2000). Different mushroom species contain distinct levels of vitamin D_2 and ergosterol. We are running a number of experiments with pre-harvest *Agaricus bisporus.* The mushrooms are treated with UV light in order to increase vitamin D_2 level. After the analysis of the first results we are planning to prepare a study about our findings.

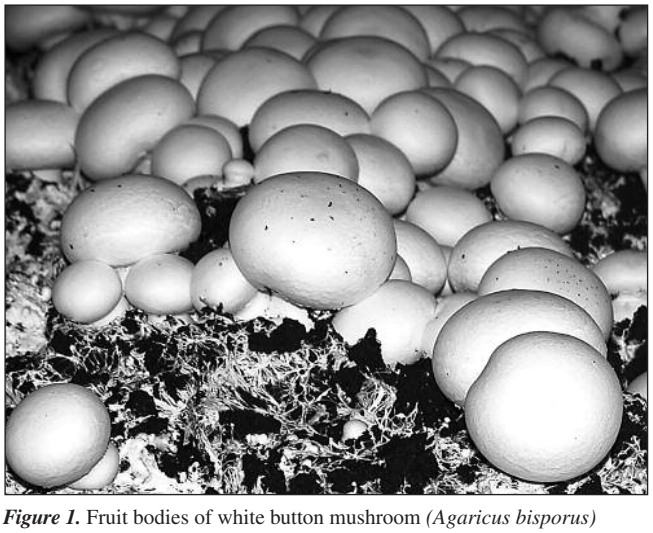

Figure 1. Fruit bodies of white button mushroom *(Agaricus bisporus)*

The data presented in this paper shows that many nutritional compounds of the cultivated mushrooms are present in a significantly higher amount than in case of the most commonly consumed vegetables and fruits.

Figure 2. Oyster mushroom (*Pleurotus* spp.)

Figure 3. Shiitake *(Lentinula edodes)* DSCN 5162

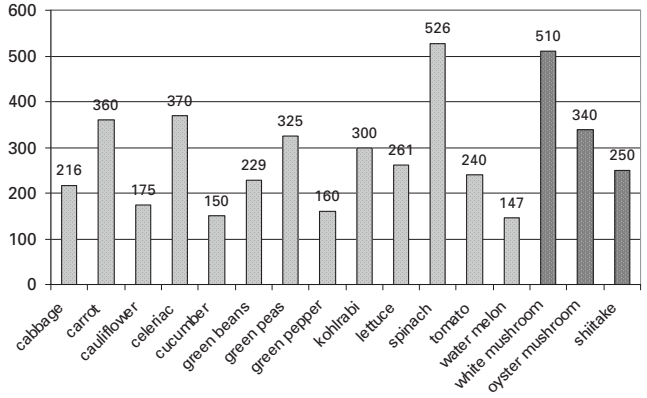

Figure 4. Average content of potassium (mg) in 100 g vegetables and mushrooms (fresh)

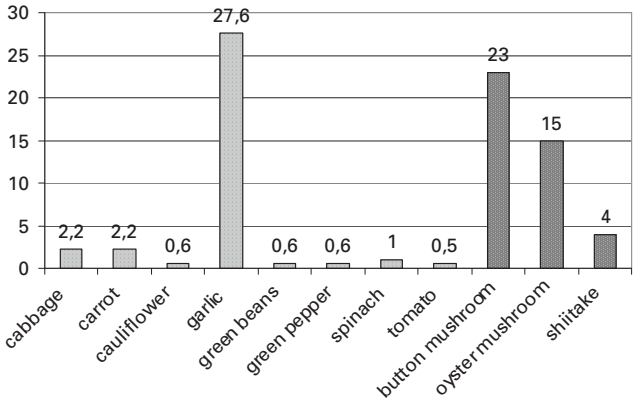

Figure 5. Average selenium content (mg) in 100 g vegetables and mushrooms (fresh)

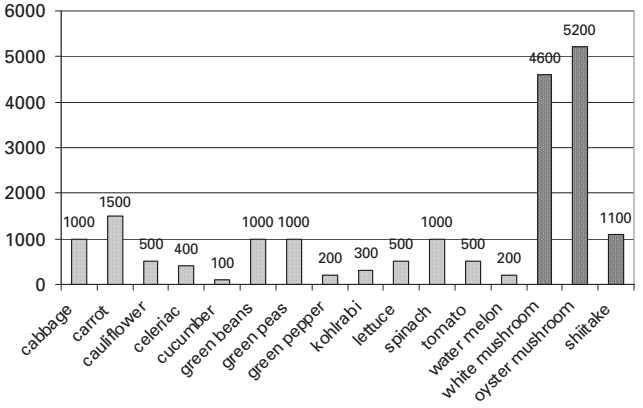

Figure 6. Average niacin content (µg) in 100 g vegetables and mushrooms (fresh)

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